UNIVERSITY OF PÉCS

Doctoral School of Earth Sciences

Geomorphic evolution on the southern foreland of the Western and Middle Mecsek Mountains, after the retreat of the Pannonian Lake

PhD thesis

Kovács István Péter

Supervisor:

Ferenc Schweitzer D.Sc.

Titusz Bugya Ph.D.

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The name of doctoral school:	PTE Doctoral School of Earth Sciences
Director:	Dr. Dövényi Zoltán PTE TTK Institute of Geography, Department of Geography of Hungary
Research group:	Geomorphology
Supervisor:	Dr. Schweitzer Ferenc PTE TTK Institute of Geography, Department of Geography of Hungary
Research field:	Geomorphology
Supervisor:	Dr. Schweitzer Ferenc PTE TTK Institute of Geography, Department of Geography of Hungary
	Dr. Bugya Titusz PTE TTK Institute of Geography, Department of Cartography and GIS

1. Introduction

The geological properties of the Mecsek Mountains have been investigated in details, over the last 60 years related to the local uranium mining and as a potential disposal site for the high-activity radioactive waste of the Paks Nuclear Power Plant (Böckh J. 1876; Vadász E. 1935; Kleb B. 1973; Koch L. 1988; Konrád Gy. 2001; Konrád Gy. – Sebe K. 2010). Only a few studies discussed its geomorphologic properties and Neogene development of the Western Mecsek Mountains (Szabó P. Z. 1931, 1935, 1955, 1964; Lovász Gy. 1970; Szilárd J. 1975; Pécsi M. et al. 1988; Schweitzer F. 2002, Schweitzer F. et al. 2005; Kovács I. P. et al. 2007; Sebe K. 2008). However it is difficult to interpret the results of former studies, because they reflect the knowledge and approach of different ages.

No detailed and large-scale geomorphological maps has been prepared for he southern part of the Middle and Western Mecsek Mountains were not made. The large-scale and detailed maps of former studies (Szilárd J. 1979; Szilárd J. – Schweitzer F. 1976, 1977; Szilárd J. – Lovász Gy. 1980) represent only the built-up area of Pécs.

The interpretation of the former geomorphological and geological studies is rendered more difficult due to their fifferent ways of presentation and the different geochronological conceptions. The chronostratigraphical and sedimentological interpretation of the Pannonian Lake and Badenian sea (pl. Pannonian s.l., Pannonian s.str and Mediterranean stage) play an important part in the surface development of the Mecsek Mountains.

Still in our days miscellaneous and inconsistent use of different geomorphic evolution theories were often observable in the professional literature. The geomorphologists used abreast incompatible terms such as the etch-plain and etch-plain steps. The theory of the pedimentation appeared in this complex and inconsistent situation in Hungary and generated disorientation and misunderstandings. The correct interpretation and consistent use of these terms is necessary to understand the evolution of the Mecsek Mountains.

The determination of the age and the origin of the denudation surfaces of the Mecsek Mountains is aggravated by the uplifting of the mountains and the absence of correlative sediments. The investigation of the foreland of the Mecsek Mountains (Görcsöny Hills and Pécs Basin) is necessary to successfully determine the origin of the denudation surfaces. The young surfaces (terraces) that were developed after the opening of the Pécs Basin could be identified here as the correlative sediments of the older denudation surfaces of the Mecsek Mountains.

According to Szabó P. Z. (1935) and Koch L. (1988) the planation surfaces of the southern slopes of Jakab Hill are tilted to the west-southwest direction. However the surfaces (of the same age and origin) on the southern slopes of the Misina-Tubes range lies horizontally (Kovács I. P. et al. 2007). This kind of tilting could affect the geomorphologic and geomorphometric properties of the denudation surfaces and the elements of the drainage network of the tilted part of surface. The tilted uplift of the area also affects the micro-geomorphological details of the valleys that dissected the area.

The position and altitudinal relation of the denudation surfaces could be determined from a geomorphological map with comprehensive and standardized legend. The details of the evolution of the Mecsek Mountains could be completed using geomorphological and geomorphometrical information and land surveys.

The Western and Middle Mecsek Mountains rise above their surroundings with a summit altitude of 592m (Jakab Hill), 540 m (Vörös Hill) and 611–535 m (Misina and Tubes Peak). The investigated area (proper) is bordered by the northern slopes of these peaks in the north, by the Nyistári Valley (west from Jakab Hill) in the west, by the Tellye in the east and by the alluvial fan of the Magyarürög Valley the south. The investigated area in a broader sense also covers the northern slopes of Pécs Basin and southern foreland of the Eastern Mecsek Mountains.

The Western Mecsek Mountains are an anticlinal structures. The Jakab Hill is composed of Upper Permian and Lower Triassic conglomerates and sandstone,s however the Misina-Tubes range is built of Middle Triassic limestones. There is a major strike-slip fault zone along the southern border of the Mecsek Mountains and the Pécs Basin, called Mecsekalja Dislocation Zone.

2. Aims

The main goal of my work was to determine the post-Pannonian geomorphic evolution of the Middle and Western Mecsek Mountains and to identify the origin and the geomorphological and geomorphometrical properties of the denudation surfaces. In the course of my work further goals emerged:

1. to interpret the special professional of the study area; to identify the complex geochronological and terminological problems of pedimentation and use correctly for the investigated area
2. to draw the 1 : 10 000 scale geomorphological map of the investigated area; to determine the position and altitudinal relation of the denudation surfaces, to determine the age and development of landforms;
3. to prepare a digital elevation model based on the 1 : 10 000 scale, *EOV* topographic map of the investigated area; to interpret and analyse the derived maps of DEM and to compare with geomorphological map;
4. to determine the geomorphometric (quantitative) properties of landforms and compare with the qualitative results of the geomorphological mapping; to correct the surface development of the study area based on the results of the geomophometrical investigations.
5. to investigate the geomorphological and geomorphometric properties of valleys, which could provide additional data to correct the geomorphic evolution of the Mecsek Mountains.
6. to survey these valleys (by detailed field survey) and create a digital elevation model based on the field data; to draw the geomorphological sketch of the valleys; to investigate and to interpret their evolution.

3. Methods

3.1. Geomorphological mapping

A 1 : 10 000 scale geomorphological map of the investigated area was drawn to determine the origin, the development, the position and altitudinal relation of the denudation surfaces. The geomorphological sketch was made using by classical geomorphological methods.

The 1 : 10 000 scale topographical map of the study area wasanalysed. However to draw a detailed 1 : 10 000 scale geomorphological map was not allowed by the extent of the area and the variety of the landforms.

The geomorphological sketch contains only the most important geomophological forms (denudation surfaces, valley bottoms etc.), without the slopes, slope angles and geological information. The geomorphological sketch was corrected according the results of the filedwork. The most important landforms and sites were documented by digital photographs. The legend and colours of the geomorphological sketch were created and used according to Pécsi M. (1963).

The map was drawn with *Inkscape* (0.47) and *Gimp* (2.6.8). The sketches of different landforms were stored on layers and were exported with 1×1 resolution. The maps of landforms were imported to a formerly defined *EOV location* of *Grass* (6.3.0).

3.2. Digital elevation model

The digital elevation map of Jakab Hill and its southern slope is based on the 14–131, 14–132, 14–133, 14–134, 14–311, 14–312 sheets of the 1 : 10 000 scale topographic map. The contour lines (increment between the contours was 2.5 m) were digitized by Péter Sági and Péter Gyurics, using the *v.digit* module of *Grass GIS*.

The contour lines were transformed to points and the points were interpolated by the *v.surf.rst* module, using the *spline interpolation* (Mitasova H. – Hofierka J. 1993; Mitasova H. – Mitas L. 1993; Mitasova H. et al. 2005). The digital elevation model has 2.5 m vertical (based on the vertical increment between the contour lines) and approx. 5 m horizontal resolution. The digital elevation model and the derived maps were produced with 1×1 resolution, in order to be compareble the geomorphological sketch.

3.3. Field survey

After the investigation the geomorphic evolution and the geomorphological properties of the study area the valley bottom of the Páprágy and Kásás Valley were surveyed. During the fieldwork the upper part of the Páprágy Valley was surveyed, which is situated higher than the built-up areas. *Sokkia SDL 50* digital leveler was used to survey the characteristic points of the terrace-like surfaces and the channel of the stream (valley floor) too if it was possible. The terrace-like surfaces, which situated far from each other, were not connected with a continuous survey. The margin of error of the field survey was about 10 cm (horizontally) due to the precision the equipment and the variety of the surface. The margin of error (vertically) was only a few cm. The real *EOV* coordinates of points were calculated from the surveyed data using by trigonometric functions. However their altitudes were relative.

During the next campaign of survey the points of the stream and the formerly measured base points of the terraces were surveyed to determine their absolute elevation and real EOV coordinates (*Sokkia SET 630 RK3)*. The vertical margin of error of the survey was about ± 0.5 m due to the elevation of the first base point. The results (data) of both campaigns were connected and used to create the digital elevation model of the valley. The floor of the Kásás Valley was surveyed using a *Sokkia SET 630 RK3 digital survey station* and data were integrated into the digital elevation model of the valley in the same manner as for the Páprágy Valley.

3.4. Measuring the recent gully erosion

I used regular field trips to observe and identify recent gully erosion on the bottom of the Páprágy Valley (valley bottom gullies). The incision on gully thalwegs was measured and documented with photos for different parts of the valley floor during the field trips. The photos of the gully bottoms and the measured incisions were compared and erosion rates were calculated. The erosion rate was used to determine the development of the valley, the gullies and the terrace-like surfaces.

3.5. Geomorphometry

The surface types, which were tilted to the west-southwest at different angles on the southern slopes of Jakab Hill, were delimited (using the results of geomorphological mapping) to calculate the dip angle of this surface type. The elevation map of the surfaces was generated from the DEM and the geomorphological map. The dip angle of the surface types was calculated from the mode, maximum and minimum values of the surfaces (surface elevation map), using the mode of the elevation of highest and lowest surface and their distance.

Cross sections were drawn across the middle and lowest surface types at Jakab Hill and the Misina-Tubes range to compare the dip angle of surface types (the DEM based on the 1 : 50 000 scale topographic map).

To prove the asymmetry of the valleys which dissected the middle and lowest surface types the areas of valley sides – whose aspect coincides with the direction of the tilting of the surface type and the opposite valley side – were compared. The area of the opposite valley sides were calculated from the derived maps of the DEM and the geomorphological map. *r.report* module of Grass GIS was used to calculate thir area.

The relation of the erosional and derasional valleys (which dissected the tilted surface types) was calculated using the DEM and the geomorphologic map to identify the other geomorphometric effect of the tilting of surface types. This investigation required first to defining the derasional-like valley. The surface types were divided tree part (parallel with the dip angle of surface types) and the relation of erosional and derasional (derasional-like) valleys were calculated and compared.

4. Results and theses

4.1. Thesis: The geological and geomorphological studies and reports of the Mecsek Mountains were analysed and interpreted. The most important conclusions of them are the following:

The geomorphologic and geologic studies of the investigated area during the last 130–140 years may pose several disputed facts and open question. The interpretation of these disputed facts are important and necessary for the interpretation and demonstration of the results of new research.

The Mediterranean transgression effected the surface development of the Western and Middle Mecsek Mountains (Szabó P. Z. 1931; Vadász E. 1935; Prinz Gy. 1936). Later the use of the terms Mediterranean stage and Mediterranean sea was rejected in Hungarian earth sciences. The abrasion platforms of the Mediterranean sea were identified and reinterpreted (using former chronostratigraphical charts) as the abrasion platforms of the Pannonian Lake.

The age of Pannonian sediments and post- and intra-Pannonian tectonic events (Vadász E. 1935; Prinz Gy. 1936; Szabó J. 1972; Kleb B. 1973; Chikánné Jedlovszky M. – Kókai A. 1983; Konrád Gy. 2004) were reinterpreted using the actual chronostratigraphical charts. The Pannonian sediments were interpreted as sediments, which were accumulated in the Pannonian Lake. The studies of Kadić O. – Kretzoi M. (1927), Kretzoi M. (1941, 1952), Magyar I. et al. (1999) és Magyar I. (2009) were used to date the extension of the Pannonian Lake.

The terrestrial biostratigrahical system published by Kretzoi M. (1969, 1983, 1985, 1987) was used to identify the chronostratigraphical substages of post-Pannonian periods. The stratigraphical position of the Pleistocene and Holocene epochs were interpreted according to the chronostratigraphical literature of the last 130–140 years.

The pediment surfaces are similar geomorphological forms to the Piedmonttreppes by Penck W. (1924) and echplain steps (Davis W. M. 1899 and Johnson D. W. 1910). Pedimentation processes characterize the geomorphic evolution of arid and semi arid regions, hence pedimentation is climatic geomorphological phenomenon. Due to these facts pedimentation is not compatible with the etch-plain steps and Piedmonttreppen. The studies of Johnson D. W. (1932), Tricart J. (1950), Birot P. (1951), Dresch J. (1957) were interpreted and glacis and pediment surfaces were separated. The pediment and glacis surfaces, which developed under periglacial climatic control, were defines as cryopediments and cryoglacis.

The so-called Panonian-Pontian desert climate (Lóczy L. – Cholnoky J. 1918) and the tropical and subtropical etchplanation (Bulla B. 1943, 1947, 1958) theory were interpreted and the paleoclimatological reconstruction and correlative sediments of pediments and glacis were summarized.

4.2. Thesis: Two (Tertiary and Quaternary) denudation surfaces were identified on the southern slope of the Western and Middle Mecsek Mountains, which developed before the opening of the Pécs Basin. The age and the origin of the formerly identified denudation surfaces were reinterpreted according to the new surface evolution theory. The defined landform types were investigated and systematized for the whole study area.

The oldest planation surfaces form the summit region of the mountain (Jakab Hill 592 m, Vörös Hill 540 m, Misina-Tubes range 535–611 m). These surfaces were categorized as the *surface type of emerged summit surfaces* (*Fig 1*). According to the former results in the geological literature (Jámbor Á. – Szabó J. 1961; Wéber B. 1982; Chikán G. 1991; Barabás A. 1993) and the results of the geomorphological mapping the development of this surface type started after the accumulation of the fluvial sediments of the Szászvári Formation and before the Badenian transgression.

The denudation surfaces at 170-360 m a.s.l., on the southern slopes of Jakab Hill and on 280–400 m a.s.l., on the southern slopes of the Misina-Tubes range are of the same age and origin, hence they were categorized as the *middle surface type*. The surfaces of the middle surface type can be interpreted according to the former literature as *abrasion platforms of the Badenian sea* (Szabó P. Z. 1931; Vadász E. 1935, Prinz Gy. 1936) and *abrasion platforms of the Pannonian Lake* (Chikánné-Jedlovszky M. – Kókai A. 1983). The terrestrial clays, which were found in the Kásás Valley, demonstrate that the Pannonian Lake reshaped the abrasion platforms of the Badenian sea. The abrasion surfaces of the middle surface type were reshaped to pediment under the semi-arid climate of the Bérbaltavárium as proved by the red clay sequence (correlative sediments) in the Posta Valley site and its altitudinal position (Pécsi M. et al. 1988, Schweitzer F. 2002). The surfaces were interpreted as Late Miocene and Early Pliocene pediments, however the southern part of the pediment (south of the Pécs Basin) is a glacis surface according to the geomorphological mapping and geological properties.

During the geomophological mapping of Zsebe Hill, Süveg Hill and Makra Hills were observed as isolted hills separated from their surroundings. These hills (situated at 280–260 and 200–210 m a.s.l.) were mapped as the *lowest surface type*. They were formed initially by the Pannonian Lake (Szabó P. Z. 1931, Vadász E. 1935, Prinz Gy. 1936, Kleb B. 1973, Pirkhoffer E. 1997).

According the reddish clays of the Posta Valley site and the terraces of the Pécs Stream the surface remnants of the lowest surface type were reshaped by the pedimentation processes under the semi-arid climate of Kislángium. These surfaces are part of the Pleistocene pediment surface of the Mecsek Mountains, which was separated from its glacis surface (Görcsöny Hills) by the Pécs Basin. The Pécs Basin was opened up 750 000 years ago from the southwest to the northeast according to information from the Posta Valley site.

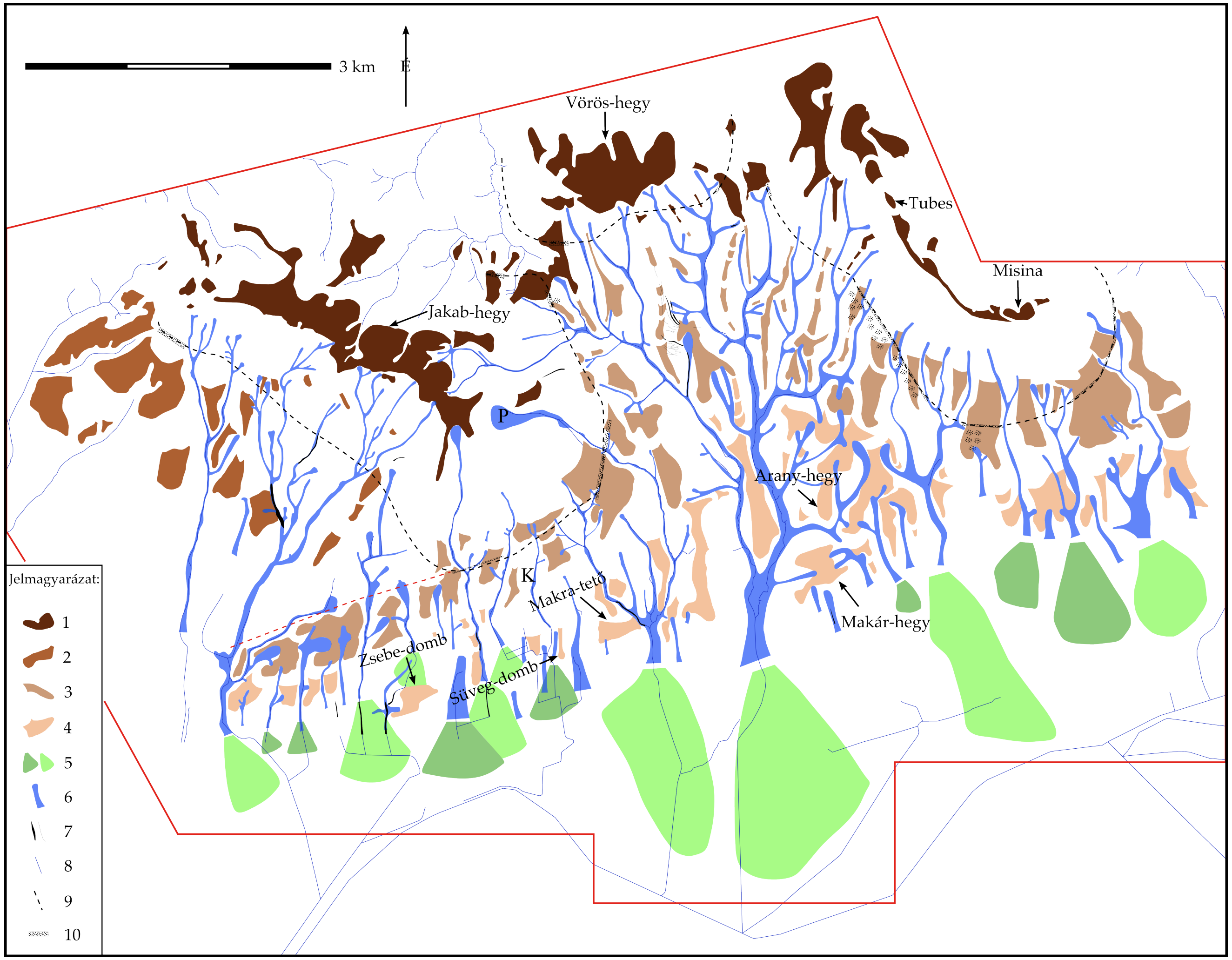

Fig 1: **The geomorphlogical sketch of the southern slopes of the Western and Middle Mecsek Mountains.**
Legend: 1 = surface type of emerged summit surfaces; 2 = surfaces of the middle surface type without age; 3 = surfaces of the middle surface type; 4 = surfaces of the lowest surface type; 5 = alluvial fans and debrish fans; 6 = valley bottoms; 7 = gullies; 8 = streams; 9 =the shoreline of the badenian sea according to Szabó P. Z. (1931) (The intermittent red line indicates the modified shoreline of badenian sea.); 10 = Badenian sediments Szabó P. Z. (1931) szerint; P = Páprágy Valley; K = Kásás Valley.
(eds.: Kovács I. P. 2010.)

4.3. The identified Late Miocene Early Pliocene and Pleistocene denudation surfaces are tilted to the west-southwest on the southern slopes of the Jakab Hill. However these surfaces aresituated in their original position on the southern slopes of the Misina-Tubes range.

Cross sections on the middle and lowest surface types prove that the surfaces of the surface types dip decreasingly to the west-southwest on the southern slope of Jakab Hill (*Fig 2*). Cross sections on the same surface types demonstrate that these surface types are situated in their original horizontal situation on the southern slopes of the Misina-Tubes range.

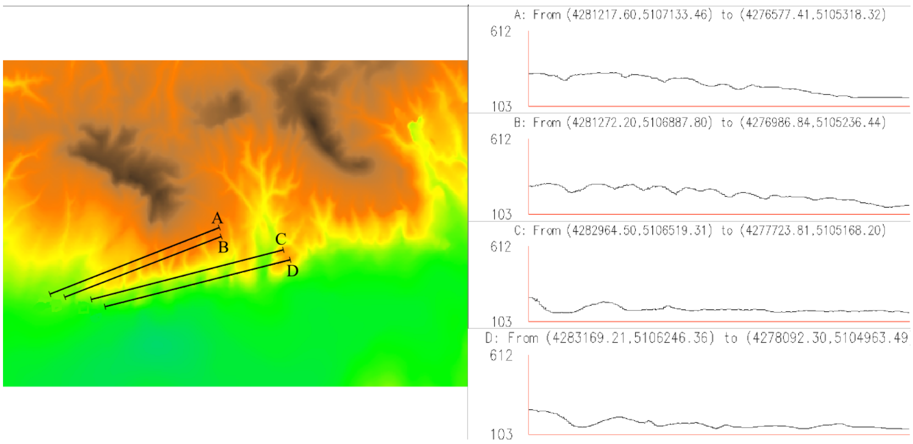

Fig 2: **Cross sections on the middle and the lowest surface types on the southern slope of Jakab Hill.**
Legend:
A, B = middle surface type; C, D = lowest surface type.
(eds.: Kovács I. P. 2010)

The mode of the elevation of the lowest surface of the middle surface type is 172 m, however the mode of the highest surface is 321 m. *2,11° dip angle of the surface type* was calculated from the vertical (149 m) and horizontal distance of the lowest and highest surface. Hence the middle surface type tilted to the west-southwest with the dip angle of 2,11° at the Jakab Hill. The standard deviation of the mode (and with the 2.11° dip angle calculated mode), the minimum and maximum values of the elevation of the surfaces demonstrate that the surfaces of the surface type behaved uniformly during the tilting (*Fig 3*). According to the comparative analysis of the *surfaces of the middle surface type are* unambiguously *characterized by the mode of the elevation of the surfaces.*

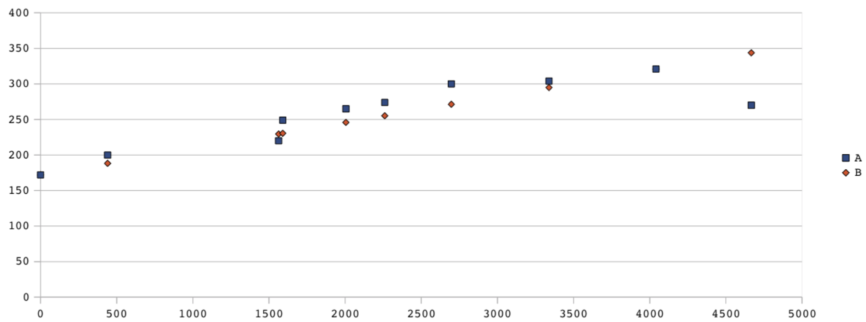

Fig 3: **The atributes which descibe the elevation of the surfaces of the middle surface type.**
A = mode of the elevation of surfaces; B = elevation of surfaces, calculated with 2.11° dip angle.
(eds.: Kovács I. P. 2010.)

The surfaces of the lowest surface type rise increasingly from the west to the north-northeast, from the 153 m up to 273 m a.s.l. The mode of the elevation of the lowest surface of the lowest surface type is 171.5 m, however the mode of the highest surface is 259.5 m. Their distance is 5820 m. The dip angle is 0.886º. Hence the lowest surface type tilted to the west-southwest with the dip angle of 0.8º. The standard deviation of the mode (and with the 0.8º dip angle calculated mode) and maximum values of the elevation of the surfaces demonstrate that *surfaces of the lowest surface type are* unambiguously *characterized by the mode and maximum values of the elevation of the surfaces.*

4.4. There is a significant correlation between the development and geomorphomterical properties of valley network and the tilting uplifting (4.3). of the middle and lowest surface types.

Jakab Hill has been tilted to theWSW after the formation of the middle and the lowest surface types, therefore the valleys (which dissected them) became asymmetric. This phenomenon was demonstrated using cross sections. According to cross sections, the length of opposite valley sides is variable. The asymmetry of valley sides also could also be demonstrated by measuring the area of opposite valley sides (geomorphometrical method). The ENE slopes of the valleys (which are perpendicular to the surface types) are steeper and shorter than the WSW slopes. This correspondence was observed both of the surface types of Jakab Hill (Fig 4). The valleys perpendicular to the surface types on the southern slopes of the Misina-Tubes range are not asymmetric according to cross sections and field observations.

The watercourses of the valleys orientated to the tilting of the surface types,begun before the valley development started. The streams flowed on the west-south-western part of the valley bottom due to the tilting of the surface types, hence WSW part of valley sides became steeper and steeper. It was observed during the field trips that the opposite (ENE) valley sides which were steeper due to the tilting of the surface types were stooped down due to the absence of linear erosion and sediment yield.

According to field observations and geomorphometric analyses, linear erosion processes (incision) and landforms prevail on the uplifting part of surface types, due to the tilting of surface types. Erosional type valleys, gullies, incised stream channels and terraces were mapped here. On the west-southwestern part of the surface types, where the uplifting is slower areal processes (sheet erosion) and landforms were observed. This phenomenon was proved by the identification ratio between the areas of erosional and derasional valleys (Fig 5) using geomorphometrical methods. There is a transitional zone between surface types intensely and less intensely uplifting. There is a balance between the areal and linear erosion processes in the transitional zone (Kásás Valley and the unnamed valley west of Kásás) according to the field observations and detailed field survey.

As the north-south directional consequence of the tilting of the surface blocks, the valleys of the lowest surface type are derasional valleys. The relative relief of the former erosional valleys have decreased and the sediment (originated to the upper, eroded slopes of the mountain) refilled the valley bottoms. This valleys became derasional valleys.

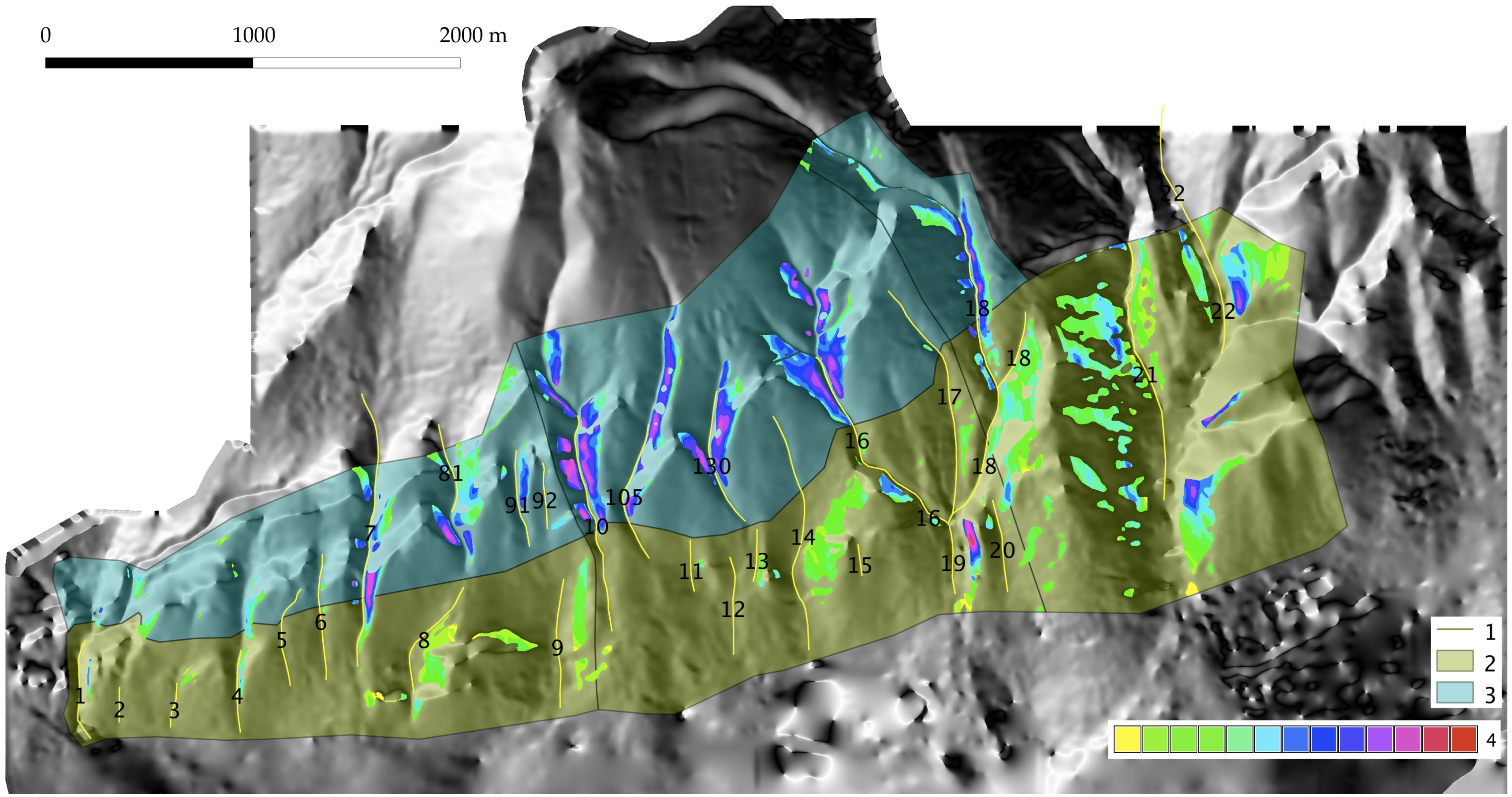

Fig 4: **Slope map of the WSW and ENE valley sides of Jakab Hill draped on the aspect map.**

1 =thalweg (and ID) of the valley; 2 = border of the lowest surface type;
3 = border of the middle surface type; 4 = categorized slope values of the valley sides (from 0–3° to 36–39°).
(eds.: Kovács I. P. 2010.)

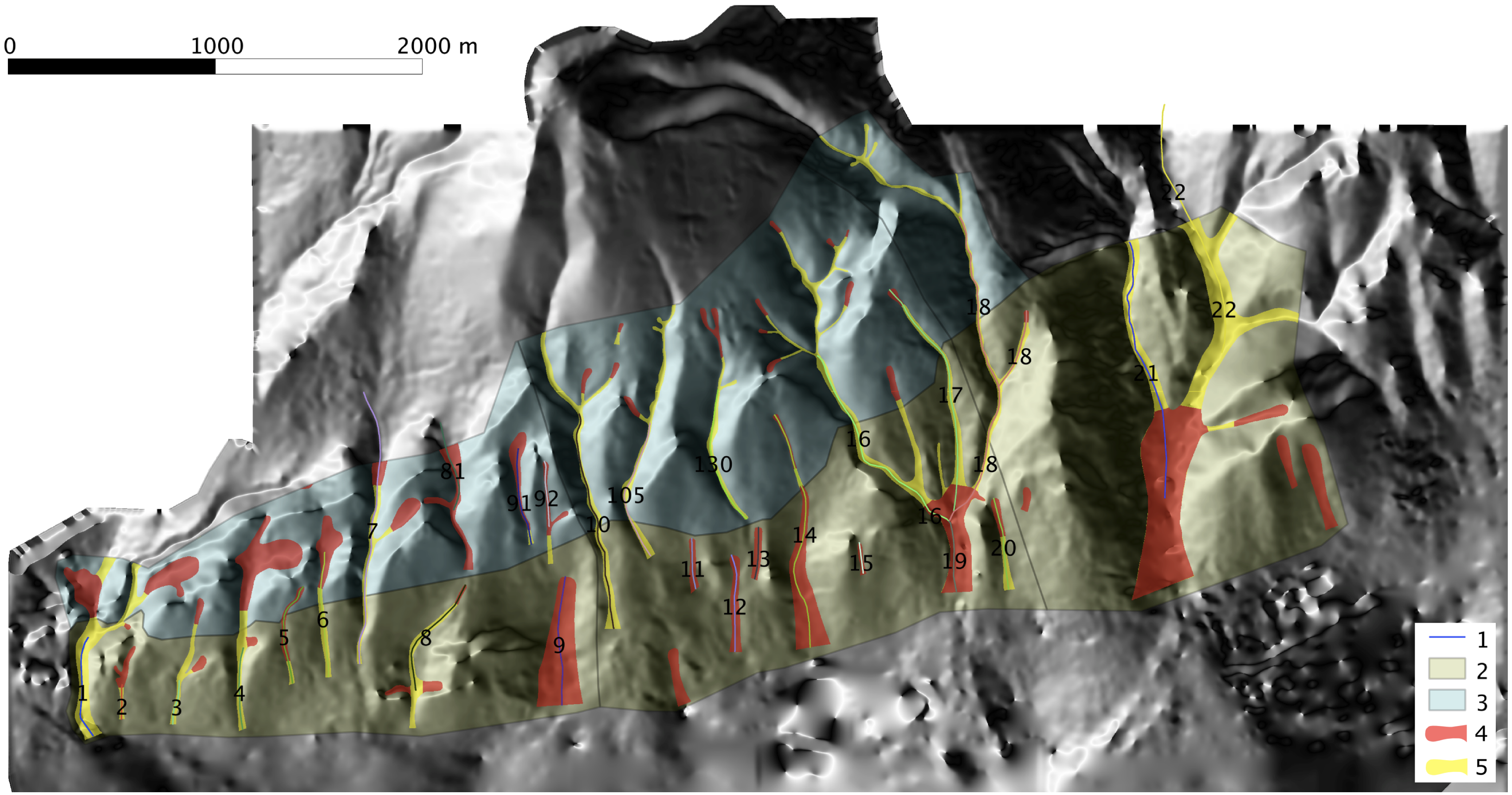

Fig 5: **The map of erosional and derasional valleys of the middle and lowest surface types of Jakab Hill draped on the aspect map**

1 = thalweg (and ID) of the valley; 2 = border of the lowest surface type;
3 = border f the middle surface type; 4 = derasion valley; 5 = erosion valley.
(eds.: Kovács I. P. 2010.)

4.5. It was identified that the effects of the tilting of Jakab Hill appeared in the major elements of the drainage network and also in the micromorphometric elements of the surface. This correspondence could be measured and proved using the detailed field survey and geomorphometric analyses.

The Páprágy Valley dissected the WSW tilted, NE part of the middle surface type of the Jakab Hill. The upper part of the valley (situated between 240–270 m a.s.l.) is perpendicular to the tilting of the surface type. According to the geomorphometric methods, the ENE slopes of the valley are shorter and steeper, while the WSW slopes are gentler and longer duo to tilting.

It was an indirect effect of the tilting of surface types, because valley bottom streams were diverged from the intensely uplifted part of surface types and valley sides far from the intense uplift were eroded to become steep. According to the geomorphological sketch, landslides may occur on the steep and undercut slopes of the asymmetric valleys, as on the opposite gentle slopes. Landslides impound the streams and the foot of the landslides fill up the valley bottom with their sediments, hence the gradient and the energy of the streams are decreasing and their sediment load is accumulating on the upper valley bottom. Below the landslide-dam the gradient, competence and the energy of the streams is increasing and the streams erode their channels.

If here, near the intense uplifting part of the tilting surface type the valley sides are not perpendicular to the direction of tilting there are few landslides. In this case the rate of incision of streams increases due to the local relief increase caused by the tilting. The intense incision of the stream channel involves a terrace development (Fig 6).

Fig 6: **Wide terrace surface and 6 m deep gully on the ESE direction part of Páprágy Valley**.
(eds.: Kovács I. P 2010)

The surveyed and detailed mapped terrace surfaces were developed due to these processes at 270–305 m a.s.l. high section the Páprágy Valley. There are only a few ENE aspect slope in this valley section, because the section is situated 45º to the tilting direction of surface type. It was identified that the valley asymmetry is not very expressed here, hence the occurrence of landslides is rare. According to the field surveys, the tilting of surface types effect geomorphologic processes in the valley. The increasing of local relief causes the incision of the stream channel and terrace development.

The change of the geomorphological processes and the spatial position of landforms, which were mapped in detail during field surveys, proved that there is a significant correspondence between the tilting of surface types and the micromorphological properties of the valley.

The Kásás Valley is a typical erosional valley, incised into the middle surface type. Its short upper part (valley head) is of derasional type, the lower part, however, is a typical erosional type valley. The valley sides are asymmetric, where the erosional section of the valley is perpendicular to the direction of the tilting of the surface type. According to the geomorphometrical investigations, the area of the WSW aspect valley sides is tree larger than the area of opposite, ENE aspect valley side.

It was justified (on the basis of field surveys) that the narrow, erosional valley bottom of the V-shaped valley spreads out to 9–20 m on 225–252 m a.s.l. and it narrows down along the lower part of the valley. The vales sides are steep, it is a typical feature of erosional valleys, however its wide and accumulated valley bottom (Fig 7) without erosion features (without any incision) proves the equilibrium between the erosion and derasion processes. The spread-out valley bottom is situated perpendicular to the direction of the tilting surface type, hence it started to develop due to the WSW tilting of the middle surface type. It was also proved by geomorphometric methods which established,that the valley asymmetry is more spectacular in this part of the valley.

***Fig 7:* The wide valley bottom of the Kásás Valley.**
(Photo by Kovács I. P. 2010)

4.6. The first phase of tilted uplift started after the Late Miocene and finished before the Early Pleistocene, however the second phase of uplifting started in the Pleistocene and it is still active today.

According to the geomorphological investigations (4.1.), the surfaces of lowest and middle surface type situated horizontally in their original position. It was proved using geomorphometrical methods that the middle surface type was tilted to the WSW with the dip angle of 2.1°, however the lowest surface tilted to the same direction with the dip angle of 0.8° (4.3).

The tilting of the middle surface started after its development in the Late Miocene (Bérbaltavárium). The surface type was tilted with the dip angle of 1.3 ° to the WSW. In my opinion there was a temporary pause in the tilted uplifting of the surface type in the Early Pleistocene (Kislángium). The surfaces of the lowest surface type were developed horizontally. After the Kislángum the uplifting was reactivated and both of the surface types were tilted to the WSW with the dip angle of 0.8° until today.

According to the mapping of the Páprágy and Kásás Valleys (4.5.), the tilting of the surface types is continuous and Jakab Hill is uplifting even in our days. It was justified by field survey of the rate of incision in the Páprágy Valley (Fig 8). The landforms (young gullies, the rate of recent downcutting and terraces) of the valley bottom of Páprágy Valley were created in historical times and their further evolution is under way. It proves that the tilted uplifting of Jakab Hill is still active.

Fig 8: **The downcutting of stream channel on the valley bottom of the Páprágy Valley (238 m a.s.l.) between 28/09/2009–11/06/2010.06.11.**

(Photo by: Kovács I. P. 2009–2010)

5. Further aims of research

The geomorphological mapping of the Middle and Western Mecsek Mountains and the investigations that were identified the geomorphological affects of the tilting of surface types raised several open questions.

Geophysical and chemical investigations of the correlative sediments originated from the denudation surfaces are necessary to determine the age of the surfaces and the start of the tilting.

The correlative sediments of the pediment and glacis surfaces (developed in the Bérbaltavárium and Kislángium) could be identified on the South Baranya and Geresdi Hills. The geomorphologic investigation of these landscapes is necessary to understand the development of the glacis and pediment surfaces of the Mecsek Mountains. One of the most important areas in this topic is the evolution of the Pécs Basin, which separated the glacis from the Mecsek Mountains.

The geophysical analysis of the clays found in the Kásás Valley, is in progress. These sediments can be an evidence of the shoreline and desiccation of the Pannonian Lake on the southern slopes of Jakab Hill. The fact of their exist is important because similar sediments are known only on the southern slopes of the Misina-Tubes range (Chikánné Jedlovszky M. – Kókai A. 1983).

However the geomorphological and geomorphometrical investigations of the surface types of the Misina-Tubes range is necessary using the same methods as for the Jakab Hill. Using this methods the boundaries of different tectonic blocks, their movements, geomorphologic, geomorphometric properties and the effect of their uplifting could be identified.

The tilted uplifting of the tectonic block caused geomorphological changes on the denudation surfaces, which are situated on the northern side of the mountain. The research of these surfaces could provide further details of the evolution of the Mecsek Mountains such as the further investigations of the tilted surface types.

The details of the valley and alluvial fan development could be identified in more detail using the information from geomorphological mapping, DEM and geological maps. However the effect of human activity should also be considered. To the further investigation of the study area a detailed geological map is needed, which contains information on the strength of sediments.

Publications and conference papers

Publications on which the thesis is based:

Kovács I. P. – Lassu T. Human impact on gully development in the southern foreland of Mecsek Mountains (Görcsöny Hills, Hungary). ***Landform Analysis*** (megjelenés alatt)

Kovács I. P. – Görcs N. L. 2010. The development of the Southern part of the Western Mecsek Mountains. In: Carestiato N. – Guaran A. (eds.): Geography of Water: Case Studies. Udine, 9 p. ISBN 978-88-8420-599-5

Bugya T. – **Kovács I. P.** 2009. Utilization of geoinformatic methods in the morphometric analysis. Case study on a mesa from Hungary: the Somló Hill. ***Revista de geomorfologie.*** (*Journal of Geomorphology)* Romanian Academy of Sciences 11. pp. 11–20.

Fábián Sz. Á. – Görcs N. L. – **Kovács I. P.** – Radvánszky B. – Varga, G. 2009. Reconstruction a flash flood event in a small catchment: Nagykónyi, Hungary. ***Zeitschrift für Geomorphologie*** 53. (2) pp. 123–138. **IF: 0,61**

Kovács I. P. – Lampért K. 2009. Lepusztulási szintek a Nyugati-Mecsek déli lejtőjén. In: Kiss T. (szerk.): Természetföldrajzi folyamatok és formák. Geográfus Doktoranduszok IX. Országos Konferenciájának Természetföldrajzos Tanulmányai. Szeged, pp. 155–166. (http://www.geo.u-szeged.hu/konf/index.html) ISBN 978-963-482-923

Bugya T. – **Kovács I. P.** 2008. Identification of geomorphological surfaces by GIS and statistical methods in Hungarian test areas. In: Lóczy D. – Tóth J. – Trócsányi A. (ed.): Progress in Geography in the European Capital of Culture 2010. Imedias Kiadó. Pécs, pp. 249–260. ISBN 978-963-87195-7-7

Kovács I. P. 2008. Újabb adatok a Somló felszínfejlődéséhez. ***Földrajzi Értesítő*** 58. (3–4) pp. 257–271.

Kovács I. P. – Lampért K. – Bugya T. – Lovász Gy. – Varga G. 2007. Planation surfaces of the Western Mecsek. ***Studia Geomorphologica Carpatho-Balcanica*** Landform Evolution in Mountain Areas 61. pp. 45–60.

Conference papers on which the thesis is based

Kovács I. P. – Mohos M. 2010. A szőlőművelés területének történelmi változása és hatása a lineáris erózió mértékére Patacs és Magyarürög példáján. Magyar Földrajzi Konferencia. Pécs, 2010.11.06.

Kovács I. P. 2010. Geomorphometric analysis of the denudation levels and erosional valleys of the Western and the Middle Mecsek Mountains (South Western Hungary).In: Lassu T. (eds.): Book of Abstracts. p. 17 International Workshop on Loess Research and Geomorphology. Pécs, 18/10/2010.

Fábián Sz. Á. – Görcs N. L. – **Kovács I. P.** – Radvánszky B. – Varga G. 2009. GIS Based flash food modelling and analysis in a small catchment: Nagykónyi, Hungary. 12th European Seminar on the Geography of Water. Udine, 2009. 07. 07.

Kovács I. P. – Lampért K. 2009: Lepusztulási szintek a Nyugati-Mecsek déli lejtőjén. Geográfus Doktoranduszok IX. Országos Konferenciája. Szeged, 2009. 03. 13.

Bugya T. – **Kovács I. P.** 2008. Utilization of geoinformation methods in the morphometric analysis. Case study Somló territory. IAG Regional Conference on Geomorphology. Abstract book p. 16. Brassó, 18/09/2008.

Kovács I. P. 2007. Térinformatikai módszerek alkalmazása deráziós völgyek elemzésében a Somló példáján. XVI. Nemzetközi Környezetvédelmi és Vidékfejlesztési Konferencia. Mezőtúr, 2007. 07. 03.

Other publications and conference papers:

Fábián Sz. Á. – **Kovács I. P.** – Radvánszky B. – Varga G. 2010. Recent landslide activity in the Tihany Peninsula (Balaton Highland, Hungary). ***Studia Geomorphologica Carpatho-Balcanica*** Landform Evolution in Mountain Areas 45. pp. 61–76.

Fábián Sz. Á. – **Kovács I. P.** – Radvánszky B. – Varga G. 2010. Csuszamlások a Ciprián-forrás (Orosz-kút) környékén: 1997–2007. In: **Kovács I. P.** – Trócsányi A. (szerk.): Tér, Tálentum, Tanítványok I. Publikon Kiadó. Pécs, pp. 135–144. ISBN 978-615-5001-02-4

Varga G. – Kovács J. – Radvánszky B. – **Kovács I. P.** 2010. A kozármislenyi feltárás faunaelemei. ***Földrajzi Közlemények*** 134. (3) pp. 267–280.

Fábián Sz. Á. – Görcs N. L. – **Kovács I. P.** – Radvánszky B. – Varga G. 2009. A tájhasználat és az antropogén geomorfológiai formák hatása a hirtelen áradások kialakulására: Nagykónyi, 2002. május 13. In: Fábián Sz. Á. – **Kovács I. P**. (szerk.): 2009. Édesvízi mészkövektől a sivatagi kérgekig. Geographia Pannonica Nova 6. pp. 167–183. ISBN 978-963-88505-1-5

Kovács I. P. 2009. Morfometriai megfigyelések a Somlón. In: Fábián Sz. Á. – Görcs N. L. (szerk.): 100 éves a Jégkorszak. A jégkorszaki klímaváltozások kutatása Penck–Brücknertől napjainkig (1909–2009). Konferencia absztrakt. p. 31.

Schweitzer F. – **Kovács I. P.** 2009. A Duna magyarországi szakaszának kialakulása a kezdetektől a folyószabályozások megindulásáig. In: Tóth J. – Aubert A. (szerk.): A Kárpát-medence etnikumai. Pécs, pp. 23–34. ISBN 978-963-88505-3-9

Kovács J. – Fábián Sz. Á. – Varga G. – **Kovács I. P.** – Varga Gy.: 2008. Thixotropic wedges or frost cracks: a review from the Pannonian basin (Hungary, Europe). In: 9th International Conference on Permafrost, Extended Abstracts. University of Alaska, Fairbanks, June 29–July 3. 2008. Fairbanks, pp. 147–148.

Kovács I. P. 2007. Adatok a Somló felszínfejlődéséhez. In: Gál V. – Szabó A. (szerk.): Tanulmányok Dr. Becsei József 70. születésnapjára a pécsi Földtudományok Doktori Iskola hallgatóitól. PTE Földrajzi Intézet, Földtudományok Doktori Iskola, Pécs, pp. 113–123. ISBN 978-963-642-135-9